TITLE

A display arrangement

TECHNICAL FIELD

Generally, embodiments of the present invention relate to a display arrangement having variable output efficiency. Particular embodiments relate to organic emissive displays having pixels with output efficiencies that vary differently.

BACKGROUND OF THE INVENTION

Organic emissive displays use an organic thin-film that emits light when a current is passed through it. The efficiency of the thin film at converting electrical current to emitted light decreases gradually over time. One type of organic emissive display is an organic light-emitting diode (OLED) display. Another is a light emitting polymer (LEP) display.

Factors that may affect the efficiency of an organic thin film include how much it has been used, how much current it is driven with, the color of the emitted light, the humidity etc.

As the efficiency of an organic thin film may decrease with use, images may become 'burnt-in' to the display. That is a darker 'ghost' of commonly displayed images may be visible in the display.

A color organic emissive display will have three different types of films. One will be used to form the red picture elements (pixels). One will be used to form the green pixels. One will be used to form the blue pixels. As the different films age differently, one or two of the colors may gradually dominate giving, for example, an image with too much green and not enough red and/or blue.

Current research into these problems is directed towards improving the 'life' of the organic materials so that their efficiency decreases over much greater periods of use/time or not at all.

BRIEF SUMMARY OF THE INVENTION

According to one embodiment of the invention there is provided a display arrangement comprising: a display comprising a plurality of pixels each of which is arranged to produce a respective output; at least a first light sensor for measuring the output of a first one of the plurality of pixels; and compensation means for receiving, from the first sensor, a first input indicative of a measured output of the first pixel and a second input indicative of a required output of the first pixel and for compensating an output control signal provided to the first pixel such that the output of the first pixel is substantially equal to the required output.

According to another embodiment of the invention there is provided a display arrangement comprising: a display comprising a plurality of pixels arranged to produce separate brightness outputs from separately received respective drive currents including a first pixel having an efficiency that varies with use; and compensation means for receiving a first input indicative of the present efficiency of the first pixel and a second input indicative of a required brightness output of the first pixel and for compensating the magnitude of a first drive current provided to the first pixel such that the brightness output of the first pixel is substantially equal to the required brightness output.

According to another embodiment of the invention there is provided a method of controlling the output of a display comprising: providing an output control signal to a first pixel of the display; measuring light output from the first pixel; and compensating the output control signal provided to the first pixel to

reduce the difference between the measured light output of the first pixel and the expected light output of the first pixel.

Embodiments of the invention may compensate overall for the effects of aging on display brightness. Embodiments of the invention may compensate for the effects of differential aging on pixel brightness. Embodiments of the invention may maintain color balance. Embodiments of the invention may prevent the ghosting of images.

A display arrangement includes a display by itself and, also, a display in combination with additional (unspecified) circuitry.

BRIEF DESCRIPTION OF DRAWINGS

For better understanding of the present invention, reference will now be made by way of example only to the accompanying drawings in which:-

Fig. 1 illustrates a portion of a prior art display;

Fig. 2 illustrates a compensated display according to one embodiment of the present invention; and

Fig. 3 illustrates a compensated display according to another embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENT(S) OF THE INVENTION

Fig. 1 schematically illustrates a portion of an organic emissive display 10. The display 10 includes a plurality of picture elements (pixels) 14. However, for clarity, the figure illustrates only three separate pixels 14_1, 14_2 and 14_3. In this example, each of the pixels 14 emits light of a different color. The pixel

14_1 emits blue light, the pixel 14_2 emits red light and the pixel 14_3 emits green light.

The organic emissive display 10 comprises an overlying common electrode 12 that is shared by the thin-film pixels 14_1, 14_2, and 14_3. Each of the pixels 14_1, 14_2 and 14_3 has a separate underlying respective pixel electrode 16_1, 16_2 and 16_3. Each of the pixel electrodes 16_1, 16_2 and 16_3 receives an input from a respective current driver 18_1, 18_2 and 18_3. The current drivers 18_1, 18_2 and 18_3 are constant current sources. The current driver 18_1 provides a drive current 19_1 to the pixel electrode 16_1 that is dependent upon a received output control signal 17_1. Typically the control signal will have one of predetermined plurality of voltages levels (grayscales). The current driver 18_2 provides a drive current 19_2 to the pixel electrode 16_2 that is dependent upon a received output control signal 17_2. The current driver 18_3 provides a drive current 19_3 to the pixel electrode 16_3 that is dependent upon a received output control signal 17_3.

Fig. 2 illustrates a portion of a compensated organic emissive display 10. The illustrated compensated emissive display 10 differs from the emissive display 10 of Fig. 1 in that it has some additional components. Otherwise, it is similar and like reference numerals are used to denote like features.

The compensated organic emissive display 10 differs from the organic emissive display 10 of Fig. 1 in that the current driver 18_2 receives a compensated output control signal 23_2 and not the output control signal 17_2. Typically the output control signal 17_2. will have one of predetermined plurality of voltages levels (grayscales).The output control signal 17_2 is received by a compensator 22_2, which compensates that signal and provides the compensated output control signal 23_2 to the current driver 18_2. The compensator 22_2 also receives a measurement signal 21_2 from a light sensor 20_2. The light sensor 20_2 is positioned adjacent the pixel 14_2 and it measures the brightness of the light output from the pixel 14_2. A light shield 24_2 shields

the light sensor 20_2 from light sources other than the pixel 14_2. Consequently, the measurement signal 21_2 is indicative to the brightness output of the pixel 14_2.

The compensator 22_2 varies the compensated output control signal 23_2 provided to the current driver 18_2 so that the brightness output of the pixel 14_2, as the efficiency as the pixel 14_2 varies, is substantially equal to that expected if the efficiency were invariant as a consequence of the output control signal 17_2.

As the efficiency of the pixel 14_2 varies, the brightness of its output without compensation is less than what the drive current 19_2 provided to the pixel electrode 16_2 would be expected to produce. Consequently, a greater compensated drive current 19_2 must be provided to the pixel electrode 16_2 to obtain the required brightness output from the pixel 14_2. This variation in the drive current 19_2 is achieved automatically by a feedback circuit that includes the pixel 14_2, its electrodes12, 16_2, the light sensor 20_2, the compensator 22_2 and the current driver 18_2. As the efficiency of the pixel 14_2 decreases, the brightness of the light detected by the light sensor 20_2 decreases, consequently the value of the measurement signal 21_2 decreases, consequently the compensator 22_2 increases the compensated output control signal 23_2 provided to the current driver 18_2, consequently the compensated drive current 19_2 increases and the output brightness of the pixel 14_2 increases to that which is expected. Thus the measurement signal 212 provides gain control of the current driver 182.

Fig. 4 illustrates one example of a compensator 22 in more detail. If the luminance output (L) of a pixel 14 is in proportion to the drive current 19 (I) provided to the pixel 14, then the output characteristics of the pixel 14 can be represented as a $L = k * I$, where L is the luminance output, k is the efficiency of the pixel and I is the drive current provided to the pixel.

If the pixel 14 has an initial efficiency of k_1, then for an input current I the required luminance is $k_1 \cdot I$. However, as the efficiency of the pixel 14 decreases to k_2, the luminance output would become $k_2 * I$. To obtain the required luminance of $k_1 \cdot I$, the current I has to be compensated by a factor of k_1/k_2 - the drive current becomes $k_1 * I / k_2$. The ratio of k_1 to k_2 corresponds to the ratio of the expected luminance, in the absence of a decrease in efficiency, for drive current I to the actual luminance produced, as a consequence of a decrease in efficiency, by drive current I.

The measurement signal 21 corresponds to the contemporaneous actual luminance of the pixel 14 and the output control signal 17 corresponds to the required luminance. Typically the output control signal 17 will have one of predetermined plurality of voltages levels (grayscales). The measurement signal 21 is divided by the output control signal 17 by multiplier 30 to produce a contemporaneous factor signal 31. This factor signal 31 corresponds to the ratio representing a contemporaneous change in efficiency. It is multiplied in multiplier 34 with the cumulative factor 33 stored in a suitable storage device 32. The result replaces the cumulative factor 33 stored in the storage device 32. The storage device 32 may be a capacitor or other memory device. The updated cumulative factor 33 is provided to a multiplier 36 where it is combined with the output control signal 17 to produce the compensated output control signal 23. As the luminance output of the pixel 14 converges to the expected luminance output, the instantaneous factor signal 31 converges to 1 and the cumulative factor 33 remains constant. Thus, the compensated output control signal 23 is held at a value that maintains the luminance output of the pixel 14 at an expected value despite a decrease in its the efficiency of the pixel 14.

Although only three pixels are illustrated in Fig. 2, the compensated display would have many hundreds or thousands of pixels of each color. Although the Fig. illustrates only a feedback loop including a single light sensor 20_2 and

single compensator 22_2, each of the red pixels could have their own corresponding feedback loop with light sensor and compensator.

Although, in the example of Fig. 2 the output of a red pixel is compensated, in other embodiments the outputs of differently colored pixels may be separately compensated instead of or in addition to the red pixels as illustrated in Fig. 3. Typically, those pixels that have a significant decrease in efficiency over their lifetime may be compensated.

Fig. 3 illustrates a portion of a compensated organic emissive display 10. The illustrated compensated emissive display 10 differs from the compensated organic emissive display 10 of Fig. 2 in that it has some additional components. Otherwise, it is similar and like reference numerals are used to denote like features.

The compensated organic emissive display 10 differs from the compensated organic emissive display 10 of Fig. 2 in that each of the blue pixel 14_1, the red pixel 14_2 and the green pixel 14_3 are compensated by their own feedback loop including a light sensor 20, compensator 22, current driver 18 and pixel 14.

The output control signal 17_1 for controlling the luminance of the blue pixel 14_1, is received by a compensator 22_1, which compensates that signal and provides the compensated output control signal 23_1 to the current driver 18_1. The compensator 22_1 also receives a measurement signal 21_1 from a light sensor 20_1. The light sensor 20_1 is positioned adjacent the blue pixel 14_1 and it measures the brightness of the light output from the blue pixel 14_1. A light shield 24_1 shields the light sensor 20_1 from light sources other than the pixel 14_1. Consequently, the measurement signal 21_1 is indicative to the brightness output of the pixel 14_1.

The compensator 22_1 varies the compensated output control signal 23_1 provided to the current driver 18_1 so that the brightness output of the blue

pixel 14_1, as the efficiency as the pixel 14_1 varies, is substantially equal to that expected if the efficiency were invariant as a consequence of the output control signal 17_1. An example of a suitable compensator 22_1 is illustrated in Fig. 4.

The output control signal 17_2 for controlling the luminance of the red pixel 14_2 is received by a compensator 22_2, which compensates that signal and provides the compensated output control signal 23_2 to the current driver 18_2. The compensator 22_2 also receives a measurement signal 21_2 from a light sensor 20_2. The light sensor 20_2 is positioned adjacent the red pixel 14_2 and it measures the brightness of the light output from the pixel 14_2. A light shield 24_2 shields the light sensor 20_2 from light sources other than the pixel 14_2. Consequently, the measurement signal 21_2 is indicative to the brightness output of the pixel 14_2.

The compensator 22_2 varies the compensated output control signal 23_2 provided to the current driver 18_2 so that the brightness output of the pixel 14_2, as the efficiency as the pixel 14_2 varies, is substantially equal to that expected if the efficiency were invariant as a consequence of the output control signal 17_2. An example of a suitable compensator 22 is illustrated in Fig. 4.

The output control signal 17_3 for controlling the luminance of the green pixel 14_2 is received by a compensator 22_3, which compensates that signal and provides the compensated output control signal 23_3 to the current driver 18_3. The compensator 22_3 also receives a measurement signal 21_3 from a light sensor 20_3. The light sensor 20_3 is positioned adjacent the green pixel 14_3 and it measures the brightness of the light output from the pixel 14_3. A light shield 24_3 shields the light sensor 20_3 from light sources other than the pixel 14_3. Consequently, the measurement signal 21_3 is indicative to the brightness output of the pixel 14_3.

The compensator 22_3 varies the compensated output control signal 23_3 provided to the current driver 18_3 so that the brightness output of the pixel 14_3, as the efficiency as the pixel 14_3 varies, is substantially equal to that expected if the efficiency were invariant as a consequence of the output control signal 17_3. An example of a suitable compensator 22 is illustrated in Fig. 4.

Although only three pixels are illustrated in Fig. 3, the compensated display would have many hundreds or thousands of pixels of each color each with their own corresponding feedback loop with light sensor and compensator.

The above embodiments, describe how the output of an individual pixel can be individually compensated because of a variation in the efficiency of the pixel. These embodiments are most suitable for use in cases where the efficiency of each pixel varies in dependence upon the use of that individual pixel e.g. its prior use, its total luminance output, the number of times it has been cycled. Organic emissive materials, particularly those used to produce green and blue light have an efficiency that varies with use. These embodiments may also be used, but are sub-optimal, where the efficiency of each pixel varies in dependence upon only common factors such as the lifetime of the pixels and their color.

If the efficiency of each pixel varies in dependence upon only common factors such as the lifetime of the pixel and their color then a single feedback circuit of light sensor and compensator may be used to compensate simultaneously all the drive currents for pixels of the same color.

Although, the above embodiments describe color organic emissive displays, monochrome displays may be similarly compensated.

In the above embodiments, the organic emissive display 10 is typically actively driven with the transistors of the current driver 18 being integrated in the same substrate as the pixels 13, the electrodes 12, 16. The light sensors

20 may also be integrated in the substrate as phototransistors or photodiodes. The compensators 22 may also be integrated in the substrate or alternatively they may be positioned off the substrate. A disadvantage of positioning the compensators off the substrate is that there is an increase of the complexity of the interconnects to the display substrate. However, if the compensators are positioned off the substrate, they may be integrated into a single processor or circuit. The term 'display arrangement' is intended include a display for which compensation is determined at the display and also a display for which compensation is determined off the display in combination with the circuitry off-display that performs the determination.

Although embodiments of the present invention have been described in the preceding paragraphs with reference to various examples, it should be appreciated that modifications to the examples given can be made without departing from the scope of the invention as claimed. For example, the compensator shown in Fig. 4 is illustrative and other designs of compensators may be used.

I/we claim: